

An acoustic liner**FIELD OF THE INVENTION**

The present invention relates to an acoustic liner and the manufacture of such acoustic liner. It also relates to use of said acoustic liner in a hot stream environment, especially in the hot area of an aircraft engine.

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BACKGROUND OF THE INVENTION

The noise due to aircraft is of critical concern to communities living around airports.

- 10 The aircraft engines are the most significant contributors to the total aircraft noise during take-off and landing. The contributing sources of engine noise are fan, compressor, combustor, turbine and jet. It is known to use acoustic liners in the engine inlets of commercial short- medium- and long-range passenger and freight aircraft in order to reduce fan noise. The acoustic liners should preferably be linear since the linear liners are acoustically more efficient than conventional liners as the 15 acoustic characteristics of the linear liners are not sensitive to changing flow and changing sound pressure levels prevailing in the engine ducts. Conventional liners on the other hand have acoustic properties that are extremely sensitive to the flow and sound pressure level.
- 20 US-A-6 176 964 describes an acoustic liner employable in jet engine housing construction for sound absorption. The liner has a solid backing sheet having a surface to which is attached a first side of a honeycomb core structure. Attached to the opposing second side of the honeycomb core structure is a mesh structure to which is attached a perforated face sheet to be exposed to the exterior. The acoustic 25 liner is designed to have linear properties while at the same time being durable in order to fulfil the requirements for use as a noise absorber in aircraft engine intakes.
- 30 With an increased burden from regulatory authorities to reduce aircraft noise, further developments of more efficient means to reduce engine noise become highly relevant and necessary. Today there are no linear liners available for use in hot stream areas of aero engines. Current liner technology regarding linear liners for engine intakes

(“cold stream”) does not meet the thermal and other functional requirements for the engine exhaust areas; the engine exhaust areas are defined as the hot stream areas, where the temperature typically is about 700°C. This has the effect that the noise environment around airports cannot be improved further as regards hot stream aero engine noise such as combustion noise.

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SUMMARY OF THE INVENTION

It is one object of the invention provide an improved acoustic liner which provides
10 more design flexibility compared to prior art liners in that the ability of optimizing the linear characteristics is improved. It is another object of the invention to reduce the noise also in the hot stream areas of the engine. Therefore according to one embodiment of the present invention an acoustic liner is provided characterized in that it comprises a layer of a metallic foam. The term “acoustic liner” is defined as a
15 liner arranged to absorb sound, i.e. attenuate sound waves. The metallic foam provides the linear characteristics to the liner. A commonly used measure for determining the linear characteristics of a sample is the so called non-linearity factor (NLF). The non-linearity factor of the inventive acoustic liner is within a range between 1.0 and 3.0 and preferably within a range between 1.0 and 2.5, for example
20 between 1.5 and 2.0.

The acoustic liner also comprises a liner core. The liner core is for example a honeycomb core or a core of metallic foam. The thickness of the liner core determines the frequency of attenuation, wherein a thin liner core provides for
25 attenuation of higher frequencies while a thick liner core provides for attenuation of lower frequencies. A first surface of the metallic foam layer can be attached directly to one side of the liner core.

In a preferred embodiment of the invention, the acoustic liner also comprises a
30 perforated sheet in combination with the foam layer. The perforated sheet strengthens the liner. Where the first surface of the foam layer is directly attached to the liner core, a second surface of said foam layer opposite said first surface, can be attached to the perforated sheet. Alternatively the perforated sheet can be arranged between the foam layer and the liner core.

- The metallic foam withstands the temperatures of hot stream areas and therefore the acoustic liner is especially adapted for use in hot stream areas. Herein hot stream areas are defined as areas wherein the service temperature is above about 400°C. The liner design does also withstand temperatures below 400°C including temperatures well below freezing, e.g. -55°C. In one application where the acoustic liner is for use in hot stream areas of aircraft engines, the metallic foam is designed to withstand temperatures around 700°C. Accordingly, the metal foam contains a metal or metal alloy having high melting temperature (characteristically about 1400°C-2000°C).
- Metals which then can be used in the foam comprise Nickel, Titanium and Chromium. The acoustic liner can also be used in other applications with a different service temperature. Then, the metallic foam should be designed for withstanding that temperature and accordingly comprise a suitable metal or metal alloy.
- The acoustic liner according to the present invention has a number of advantages over the prior art. Firstly, it can withstand hot stream environments. Further, its three-dimensional structure increases the design freedom and possibility of optimizing the linear properties (acoustic behavior) compared to what is possible with prior art liners. For instance, the cell size and cell distribution, degree of open cells, foam density, flow resistance et cetera can be tailored and optimized. Moreover, the inventive acoustic liner attenuates sound for a broad frequency band. This is a very important feature of an acoustic liner for use in hot stream areas of aircraft engines, since the noise in these areas has a relatively broad spectra. The inventive acoustic liner is light in weight and the cost of manufacture and mounting would be comparable to the costs for liners existing today.
- The present invention further includes a use of a liner including a metal foam layer as an acoustic liner.
- The present invention also includes a method of manufacturing an acoustic liner, said method is characterized in that a top sheet including a metallic foam layer is brazed onto one side of a liner core. In a preferred embodiment the top sheet is formed by brazing a perforated sheet onto the foam layer. Further, the acoustic liner can be

joined to a backing sheet by brazing, thereby providing a joint that withstand the hot stream environment.

5 DESCRIPTION OF THE DRAWINGS

The figure shows an example of an acoustic liner according the invention.

PREFERRED EMBODIMENTS

- 10 In the figure, a panel 1 is shown in the form of an acoustic liner. The panel 1 is designed to withstand hot stream environments and therefore can be used as a noise absorber for example in aircraft engine outlets.
- 15 The panel 1 comprises a liner core 2 and a top sheet assembly 5. The core 2 is attached to a solid backing sheet 6, which is impervious. The top sheet assembly 5 includes a layer 3 of a metallic foam and a perforated sheet 4. The liner core 2 is for example conventional honeycomb core made of Titanium, Nickel or Chromium, or an alloy including one or more of said metals. However, the honeycomb core can be made of any metal or metal alloy withstanding the hot stream environment (typically about 700°C of an aircraft engine). Alternatively, the line core 2 can be made of a metallic foam. Metallic foams will be described more in detail below. The thickness of the liner core 2 determines in which frequency band the panel 1 attenuates sound. A thin core 2 attenuates higher frequencies and a thick core 2 attenuates lower frequencies. A person skilled in the art can by using simple calculations determine a proper thickness of the core in order to attenuate a desired frequency band. The acoustic characteristics of the panel 1 originate from the top sheet assembly 5 and therefore the design of the liner core 2 is not essential except for the thickness of the core, and as long as the core 2 can withstand the hot stream environment.
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30 The metallic foam layer 3 comprises a metal or a metal alloy withstanding the hot stream environment (typically 700° for aircraft engines). For example, Nickel, Titanium or Chromium is chosen for the metallic foam. Alternatively a metal alloy is chosen, for example including Nickel, Titanium and/or Chromium. The metal foam is for example in the order 1-3 mm thick with small, open cells. In accordance with

one embodiment all of the cells are open while in an alternative embodiment only a part of the cells are open. The foam has a resistance to air flow which can be optimized by fine-tuning the cell size and the density of the metallic foam in order to achieve a substantially linear liner. This will be discussed more in detail below. The 5 metallic foam layer 3 is brazed to the liner core 2 or attached to it by means of another method giving an attachment notwithstanding the 700°C service temperature of the aircraft engine.

The perforated sheet 4 is made of metal, eg Nickel, Titanium or Chromium. The 10 perforated sheet 4 is arranged to strengthen the liner 1. The perforated sheet 4 has non-linear characteristics and its NLF (=non-linearity factor) value, which will be described more in detail below, is determined by the porosity of the perforate. The 15 perforated sheet 4 is brazed to the metallic foam layer 3 or attached to it by means of another method not clogging the foam and giving an attachment notwithstanding the 700°C service temperature of the aircraft engine.

The linearity of the acoustic liner is determined by the linear characteristics of the top layer assembly 5; the liner core has, as discussed above, practically no influence 20 on the linearity of the liner. An ideal linear liner has a NLF value of 1. The NLF is defined as

$$NLF = \frac{R_{at\ 200cm/sec}}{R_{at\ 20cm/sec}}, \text{ wherein } R \text{ is the flow resistance of a sample tested.}$$

By performing flow resistance tests on samples and modifying the samples in accordance with the results, a top sheet assembly 5 can be developed having a NLF 25 value close to 1, for example in the range 1.5 – 2.0. The non-linear characteristics of the perforated sheet is compensated by the design flexibility of the metallic foam material. In the testing, the characteristics of perforated sheet samples could be tested separately and the characteristics of metallic foam layer samples could be tested 30 separately. The characteristics of a tested foam layer sample and a tested perforated sheet sample can thereafter be superposed in order to obtain the characteristics of a

potential top sheet assembly. The brazing of the perforated sheet onto the metallic foam layer has no effect on the acoustic properties of the liner.

The herein described top sheet assembly 5 includes the metallic foam layer 3 and the perforated sheet 4. However, an acoustic liner with desired characteristics could be achieved even without the perforated sheet. Further, in the herein described example the metallic foam layer 3 of the top sheet assembly is joined to the liner core 2 while the perforated sheet 4 faces the environment. This arrangement provides a durable liner. Alternatively, the perforated sheet 4 can be joined to the liner core and the metallic foam layer 3 arranged on the opposite side of the perforated sheet.

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